# A SEQUENTIAL SAMPLER FOR EVALUATING SHORT-TERM OCCUPATIONAL EXPOSURE


Steven H. Hoke
U. S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD 21005
Tel: (410) 278-2269; Fax: (410) 278-3813; e-mail: Steven.Hoke@apg.amedd.army.mil
Mark F. Arnold
U. S. Army Medical Materiel Development Activity, Fort Detrick, MD 21702
Thomas D. Holmes[1]
U. S. Army Aberdeen Test Center, Aberdeen Proving Ground, MD 21005



## ABSTRACT

Exposures of occupants in armored vehicles to toxic gases produced from automatic fire extinguishing systems are difficult to measure and evaluate because they last for a relatively short period of time. Real-time measurement instrumentation is often expensive and/or difficult to operate; therefore, there is a need for simple and more cost effective methods to obtain real-time data. A sequential sampler has been developed to take grab samples over relatively short periods of time, thus producing delayed but near real-time data. A desk top computer downloads the sampling program, which includes sample time and delay time between samples, into the non-volatile memory of the sampler's onboard microcomputer. The microcomputer opens and closes solenoid valves during the sampling sequence. An external vacuum source provides air flow and metering valves control the air flow rate through the sample media. The specific gas of interest determines which sampling media is to be used. Approved analytical procedures analyze the media and provide short time slices of time-weighted-average information that can be used for accurate occupational exposure evaluation. This sequential sampler has proven to be a light, rugged, portable, easy to operate, and relatively inexpensive field sampling device.



**KEYWORDS:** Gas analysis; grab samples; air toxics; exposure assessment.


## INTRODUCTION

During fire suppression testing at the Aberdeen Test Center, many types of toxic gases can be produced from the burning of fuel, the burning of onboard material and munitions, and from the thermal degradation of the fire suppression agent. In order to evaluate the crews' exposure levels to these toxic gases, the concentrations of these gases need to be measured in real-time using validated analytical procedures. Since these tests are normally conducted under field conditions, the use of sophisticated equipment which requires highly trained and experienced operators can be prohibitively expensive. To

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[1] *Current address: Thomas D. Holmes, Aerosol Science Department, Lovelace Respiratory Research Institute, 2425 Ridgecrest Dr. SE, Albuquerque, NM 87108*

solve this problem our laboratory decided to build a sequential sampler which would be easy to use in the field, small and rugged enough to deploy inside an armored vehicle during fire tests, and would have the capability of being programmed differently for each test. A 50-cal. 100-round ammo box was an obvious choice of packaging for the sampler since these are readily available and they are often used for stowage in armored vehicles.

## EXPERIMENTAL

Figure 1 shows a schematic of the sequential sampler. An external vacuum source supplies vacuum to a manifold (#15481-6, Clippard Instrument Laboratory, Inc., 7390 Colerain Ave., Cincinnati, OH 45239) onto which are mounted five solenoid valves (#ET-2M-12, Clippard). Five metering valves (#SS-4MG, Nupro Company, 4800 E. 345th Street, Willoughby, OH 44094) are plumbed to each of the solenoid valves to control the air flow rate through the sampling media.

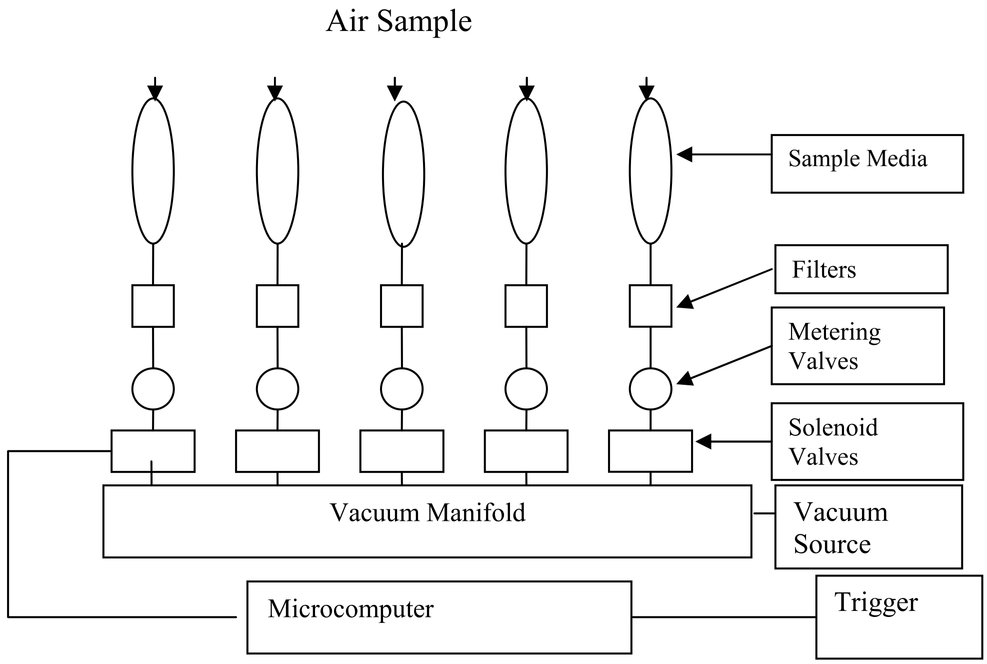


**Figure 1. Schematic of the sequential sampler.**

The metering valves (figure 2) provide a means to control the flow rate and can be adjusted to meet the specific flow rate requirements of the sampling media of choice.  The solenoid valves open for a predetermined amount of time, and close independently until the sampling event has been completed.  The valves remain closed both before and after the sampling event.  Each valve is attached to the vacuum manifold which is the source of air flow for the sampling system.

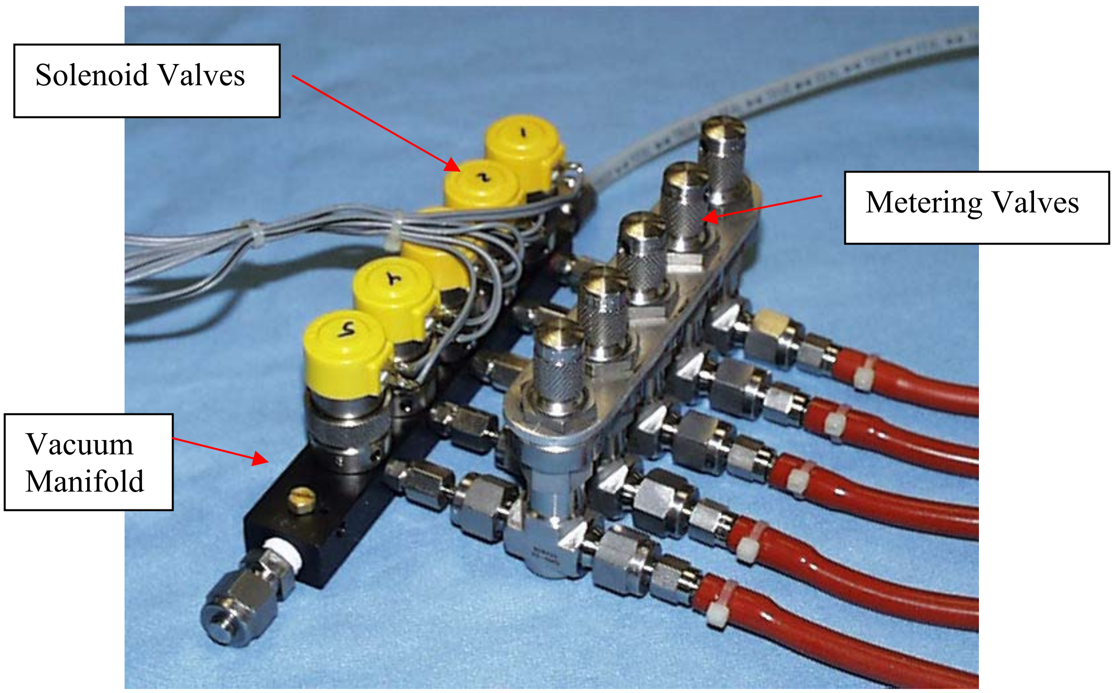


**Figure 2.  Vacuum manifold and control valves removed from the sampler.**

A microcontroller (Basic Stamp Model BS2P2401C, Parallax Inc., Rocklin, CA  95765), provides operation and control to the five solenoid valves (Figure 3). In this application the controller program is initiated by a relay which is activated by an external contact closure.  The controller opens all five of the solenoid valves simultaneously and proceeds to close them sequentially based on a predetermined schedule.

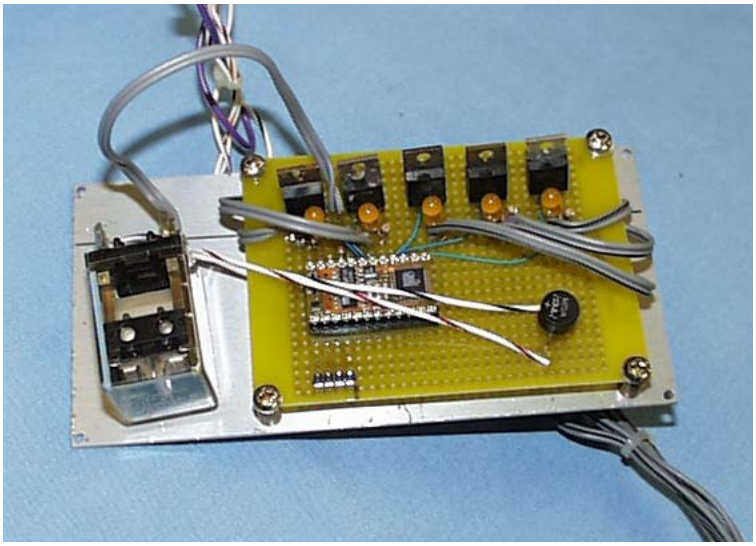

**Figure 3. Electronic control board of the sequential sampler.**

An external computer down loads the sampling sequence onto the stamp microcomputer. Sampling can be repeated for each sample when composite sampling is required.

A convenient reset switch (not shown) has been installed in case the sampling sequence is accidentally triggered and needs to be reinitiated.

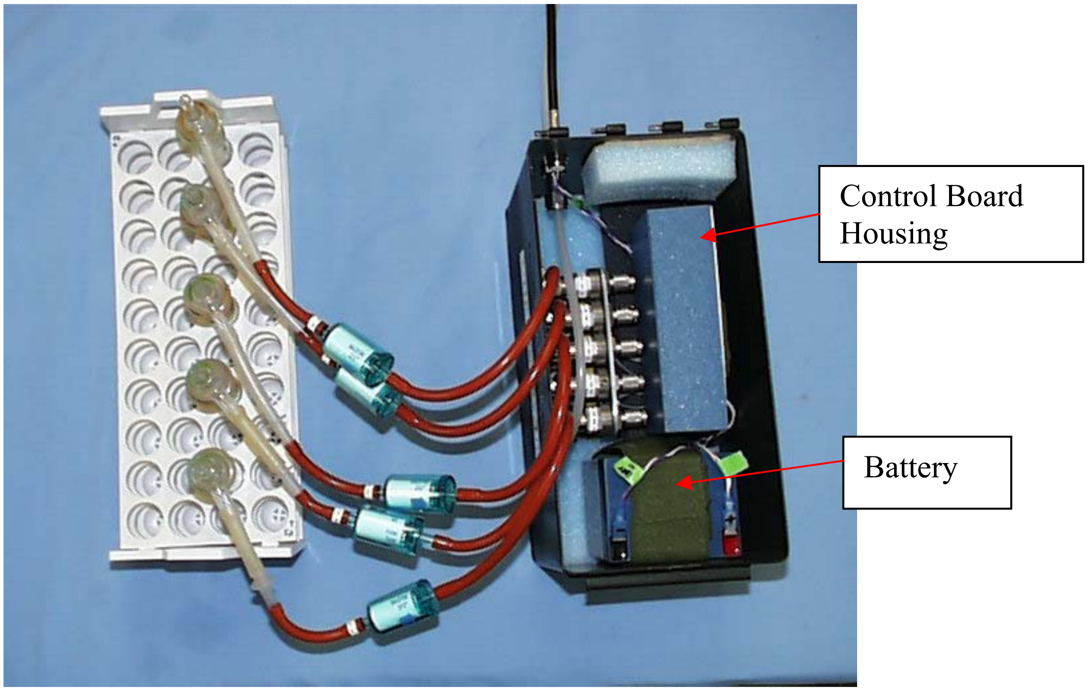


**Figure 4. Top view of the sequential sampler configured for impinger sampling.**

In figure 4 the sequential sampler is configured to take five sequential impinger samples. The distance between the impingers and the sampler can vary to accommodate the test scenario. Note the in-line filters between the sampling media and the sampling manifold. Filters placed downstream from the sampling media prevent any particulate matter from entering the metering or solenoid valves. The 12 VDC battery is also shown which provides power to the solenoid valves and the microcomputer.

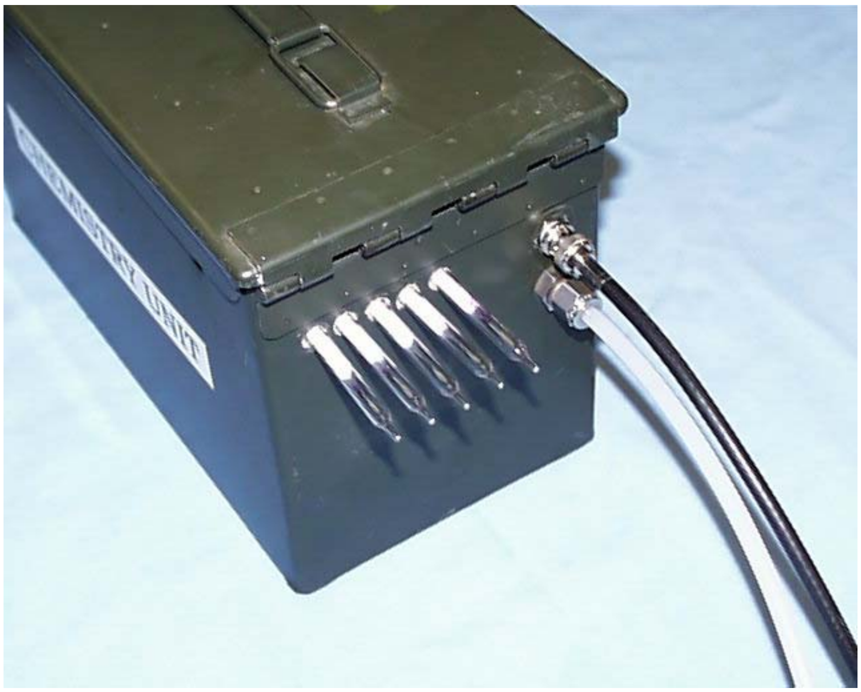

**Figure 5. External connections and sorbent tube configuration.**

Figure 5 shows the sequential sampler with a BNC connector for the remote trigger line and a ¼-in. Swagelok™ connector for the vacuum source. The configuration for sorbent tube sampling provides a more compact sampling unit for field use, especially where space is limited.

A covered switch on the outside of the sampler initiates the microcomputer at the test site and prepares the sampler for a trigger signal (Figure 6). In the field this is a very useful feature because one can determine at a glance whether the sampler is in the "on" or "off" position. Between tests the external charger plug allows for convenient recharging of the 12 VDC battery.

**Figure 6. External charger and switch of the sequential sampler.**

The unit measures 14.6 x 33 x 18.4 cm and weighs 6.2 kg.

## RESULTS AND DISCUSSION

The sampling media are off-the-shelf and can be chosen depending on the particular gas of interest. Midget impingers were the media of choice for our studies; however, sorbent tubes take up less space and are less susceptible to breakage in field situations.

The stamp is the same microcomputer technology found in autos and computer mice. It has the capability to store hundreds of instructions and execute them. In addition to being able to take hundreds of samples, additional devices can be added to the microcomputer including real time clocks, analog to digital converters to convert real time data for temperature, pH, or pressure to digital format for storage and analysis. Also, key pads and displays can be added to change data collection parameters in the field.

In this application the sampler is started remotely to coordinate sample collection with other test parameters; however, the sampler can start from a predetermined time any time after power up. It has infinitely variable sample time for each sample and delay time between samples.

By taking short time slices of a toxic gas exposure event, it is possible to obtain near real-time sampling information. In cases where the concentration of gases are anticipated to be too low to measure over a short period of time, one of the sampling media can be programmed to collect sample over the whole sampling event thus providing an opportunity to measure the time-weighted- average over the entire event.

Because of its versatile programmability this sampler can be used to measure ceiling concentrations, such as during events that produce dangerous exposure levels occurring at certain times during the normal workday. It can also be programmed to sample during events suspected of producing toxic gases in order to assist in recommending the wearing or type of personal protective equipment necessary or evaluating engineering methods for removing toxic gases.

The following table shows approximate detection limits assuming a flow rate of 1 LPM for the impingers and 0.2 LPM for the sorbent tubes.

**Table 1. Detection limits for impingers and sorbent tubes in ppm.**

| Sample Time | Impinger | Sorbent Tube |
|---|---|---|
| 10 sec. | 38 | 94 |
| 30 sec. | 13 | 32 |
| 60 sec. | 6.4 | 16 |
| 5 min. | 1.3 | 3.2 |

These detection limits can vary depending on the flow rates used for the sampling media and the detection limits of the analytical methods used for analyzing the sampling media. For example, by optimizing the detection limit of the ion chromatograph for fluoride ion, a ten-fold improvement in detection over the ones shown on the above table can be obtained for hydrogen fluoride and most other acid gas measurements.

## CONCLUSION

This sequential sampler has been used successfully to support exposure level evaluations during automatic fire suppression tests at Aberdeen Proving Ground. It has proven to be portable, easy to program, and very easy to deploy at test time. The authors are unaware of any other samplers on the market that can provide this level of programmable latitude for sequential sampling.

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